

CLAIMS

1. A switching regulator that is a step-down switching regulator for converting a voltage applied on 5 an input terminal to a predetermined voltage and outputting the predetermined voltage from an output terminal, said switching regulator comprising:

a switching transistor formed from a PMOS transistor configured to switch ON or switch OFF output 10 of the input voltage according to a control signal input to a control electrode;

a smoothing circuit configured to smooth the output voltage from the switching transistor and output the smoothed voltage to the output terminal;

15 a selection circuit configured to control connection of a substrate gate of the switching transistor according to the input control signal; and

a switching transistor control circuit configured to control a switching operation of the 20 switching transistor so that the voltage output from the output terminal becomes the predetermined voltage;

wherein

the selection circuit connects the substrate gate to a drain of the switching transistor when the 25 voltage on the input terminal is less than or equal to

the voltage on the output terminal, and connects the substrate gate to a source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal.

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2. The switching regulator as claimed in claim 1, further comprising:

a selection control circuit that compares the voltage on the input terminal to the voltage on the 10 output terminal, and controls the selection operation of the selection circuit according to a comparison result;

wherein

the selection control circuit controls the selection circuit to connect the substrate gate to the 15 drain of the switching transistor when the voltage on the input terminal is less than or equal to the voltage on the output terminal, and controls the selection circuit to connect the substrate gate to the source of the switching transistor when the voltage on the input 20 terminal is greater than the voltage on the output terminal.

3. The switching regulator as claimed in claim 1, wherein

25 the selection operation of the selection

circuit is controlled by an external selection control circuit according to the voltage on the input terminal and the voltage on the output terminal so that the selection circuit is controlled to connect the substrate 5 gate to the drain of the switching transistor when the voltage on the input terminal is less than or equal to the voltage on the output terminal, and connect the substrate gate to the source of the switching transistor when the voltage on the input terminal is higher than the 10 voltage on the output terminal.

4. The switching regulator as claimed in claim 2, further comprising:

a switching circuit that connects a gate of 15 the switching transistor to the drain of the switching transistor;

wherein

when the voltage on the input terminal is less than or equal to the voltage on the output terminal, 20 based on a control signal from the selection control circuit, the switching circuit connects the gate of the switching transistor to the drain of the switching transistor while the switching transistor control circuit stops output of the control signal to the gate of the 25 switching transistor; and

when the voltage on the input terminal is greater than the voltage on the output terminal, based on the control signal from the selection control circuit, the switching circuit disconnects the gate of the 5 switching transistor from the drain of the switching transistor while the switching transistor control circuit outputs the control signal to the gate of the switching transistor.

10               5. The switching regulator as claimed in claim 4, wherein the switching circuit includes a field effect transistor (FET).

15               6. The switching regulator as claimed in claim 1, wherein the selection circuit includes a field effect transistor (FET).

20               7. The switching regulator as claimed in claim 4, wherein the smoothing circuit includes a synchronization rectification transistor that is connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,  
wherein  
25               the switching transistor, the synchronization

rectification transistor, the selection circuit, the selection control circuit, the switching transistor control circuit, and the switching circuit are integrated into one IC chip.

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8. The switching regulator as claimed in claim 4, wherein the smoothing circuit includes a synchronization rectification transistor that is connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,

wherein

the switching transistor, the synchronization rectification transistor, the selection circuit, the switching transistor control circuit, and the switching circuit are integrated into one IC chip.

9. A power supply circuit, comprising:  
one or more step-down switching regulators  
20 configured to convert a voltage applied on an input terminal to a predetermined voltage and output the predetermined voltage from an output terminal; and  
one or more linear regulators;  
wherein  
25 the switching regulator includes

a switching transistor formed from a PMOS transistor configured to switch ON or switch OFF output of the input voltage according to a control signal input to a control electrode;

5                   a smoothing circuit configured to smooth the output voltage from the switching transistor and output the smoothed voltage to the output terminal;

10                  a first selection circuit configured to control connection of a substrate gate of the switching transistor according to the input control signal, the first selection circuit connecting the substrate gate to a drain of the switching transistor when the voltage on the input terminal is less than or equal to the voltage on the output terminal, and connecting the substrate gate to a source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal; and

15                  a switching transistor control circuit configured to control a switching operation of the switching transistor so that the voltage output from the output terminal becomes the predetermined voltage.

10. The power supply circuit as claimed in claim 9, wherein the linear regulator comprises:

25                  a voltage control transistor that includes a

PMOS transistor configured to control a current from the input terminal to the output terminal to control the voltage on the output terminal;

a second selection circuit configured to  
5 control connection of the substrate gate of the voltage control transistor;

a second switching transistor control circuit configured to control a switching operation of the switching transistor so that the voltage output from the  
10 output terminal becomes the predetermined voltage;

a second selection control circuit that controls the selection operation of the selection circuit according to the voltage on the input terminal and the voltage on the output terminal, the second selection  
15 circuit connecting the substrate gate to a drain of the voltage control transistor when the voltage on the input terminal is less than or equal to the voltage on the output terminal, and connecting the substrate gate to a source of the voltage control transistor when the voltage  
20 on the input terminal is greater than the voltage on the output terminal; and

a voltage control transistor control circuit configured to control the voltage control transistor so that the voltage output from the output terminal becomes  
25 the predetermined voltage.

11. The power supply circuit as claimed in  
claim 9, wherein the switching regulator further  
comprises:

5           a first selection control circuit that  
compares the voltage on the input terminal to the voltage  
on the output terminal, and controls the selection  
operation of the first selection circuit according to a  
comparison result;

10           wherein  
                the first selection control circuit controls  
the first selection circuit to connect the substrate gate  
to the drain of the switching transistor when the voltage  
on the input terminal is less than or equal to the  
15          voltage on the output terminal, and controls the first  
selection circuit to connect the substrate gate to the  
source of the switching transistor when the voltage on  
the input terminal is greater than the voltage on the  
output terminal.

20  
                12. The power supply circuit as claimed in  
claim 9, wherein  
                the selection operation of the first selection  
circuit is controlled by an external selection control  
25          circuit according to the voltage on the input terminal

and the voltage on the output terminal so that the first selection circuit is controlled to connect the substrate gate to the drain of the switching transistor when the voltage on the input terminal is less than or equal to  
5 the voltage on the output terminal, and connect the substrate gate to the source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal.

10                 13. The power supply circuit as claimed in  
claim 11, wherein the switching regulator further  
comprises:

15                 a switching circuit that connects a gate of  
the switching transistor with the drain of the switching  
transistor;

                      wherein  
                      when the voltage on the input terminal is less  
than or equal to the voltage on the output terminal,  
based on a control signal from the first selection  
20 control circuit, the switching circuit connects the gate  
of the switching transistor to the drain of the switching  
transistor while the switching transistor control circuit  
stops output of the control signal to the gate of the  
switching transistor; and

25                 when the voltage on the input terminal is

greater than the voltage on the output terminal, based on  
the control signal from the first selection control  
circuit, the switching circuit disconnects the gate of  
the switching transistor from the drain of the switching  
transistor while the switching transistor control circuit  
outputs the control signal to the gate of the switching  
transistor.

14. The power supply circuit as claimed in  
claim 13, wherein the smoothing circuit includes a  
synchronization rectification transistor that is  
connected to the switching transistor in series and  
controlled by the switching transistor control circuit to  
be switched on or switched off,

wherein  
the switching transistor, the synchronization  
rectification transistor, the first selection circuit,  
the first selection control circuit, the switching  
transistor control circuit, the switching circuit, and  
the linear regulator are integrated into one IC chip.

15. The power supply circuit as claimed in  
claim 13, wherein the smoothing circuit includes a  
synchronization rectification transistor connected to the  
switching transistor in series and controlled by the

switching transistor control circuit to be switched on or switched off,

wherein

the switching transistor, the synchronization  
5 rectification transistor, the first selection circuit,  
the switching transistor control circuit, the switching  
circuit, and the linear regulator are integrated into one  
circuit, and the linear regulator are integrated into one  
IC chip.

10 16. A power supply circuit, comprising:

a plurality of step-down switching regulators  
each configured to convert a voltage applied on an input  
terminal to a predetermined voltage and output the  
predetermined voltage from an output terminal,

15 wherein

each of the switching regulators includes  
a switching transistor formed from a PMOS  
transistor configured to switch ON or switch OFF output  
of the input voltage according to a control signal input  
20 to a control electrode;

a smoothing circuit configured to smooth  
the output voltage from the switching transistor and  
output the smoothed voltage to the output terminal;

25 a selection circuit configured to control  
connection of a substrate gate of the switching

transistor according to the input control signal, the selection circuit connecting the substrate gate to a drain of the switching transistor when the voltage on the input terminal is less than or equal to the voltage on 5 the output terminal, and connecting the substrate gate to a source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal; and

a switching transistor control circuit  
10 configured to control a switching operation of the switching transistor so that the voltage output from the output terminal becomes the predetermined voltage.

17. The power supply circuit as claimed in  
15 claim 16, wherein the switching regulator further comprises:

a selection control circuit that compares the voltage on the input terminal to the voltage on the output terminal, and controls the selection operation of 20 the selection circuit according to a comparison result;

wherein

the selection control circuit controls the selection circuit to connect the substrate gate to the drain of the switching transistor when the voltage on the 25 input terminal is less than or equal to the voltage on

the output terminal, and controls the selection circuit to connect the substrate gate to the source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output  
5 terminal.

18. The power supply circuit as claimed in claim 16, wherein the selection operation of the selection circuit is controlled by an external selection control circuit according to the voltage on the input terminal and the voltage on the output terminal so that the selection circuit is controlled to connect the substrate gate to the drain of the switching transistor when the voltage on the input terminal is less than or  
10 equal to the voltage on the output terminal, and connect the substrate gate to the source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal.  
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20 19. The power supply circuit as claimed in claim 17, wherein the switching regulator further comprises:

a switching circuit that connects a gate of the switching transistor with the drain of the switching  
25 transistor;

wherein

when the voltage on the input terminal is less than or equal to the voltage on the output terminal, based on a control signal from the selection control circuit, the switching circuit connects the gate of the switching transistor to the drain of the switching transistor while the switching transistor control circuit stops output of the control signal to the gate of the switching transistor; and

when the voltage on the input terminal is greater than the voltage on the output terminal, based on the control signal from the selection control circuit, the switching circuit disconnects the gate of the switching transistor from the drain of the switching transistor while the switching transistor control circuit outputs the control signal to the gate of the switching transistor.

20. The power supply circuit as claimed in  
claim 19, wherein the smoothing circuit includes a synchronization rectification transistor that is connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,

25 wherein

the switching transistor, the synchronization rectification transistor, the selection circuit, the selection control circuit, the switching transistor control circuit, and the switching circuit are integrated  
5 into one IC chip.

21. The power supply circuit as claimed in claim 19, wherein the smoothing circuit includes a synchronization rectification transistor that is  
10 connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,

wherein

the switching transistor, the synchronization rectification transistor, the selection circuit, the switching transistor control circuit, and the switching circuit are integrated into one IC chip.

22. A secondary cell charging circuit,  
20 including a step-down switching regulator configured to convert a voltage applied on an input terminal to a predetermined voltage and output the predetermined voltage from an output terminal, a secondary cell being connected to the output terminal,

25 wherein

the switching regulator comprises:

a switching transistor formed from a PMOS transistor configured to switch ON or switch OFF output of the input voltage according to a control signal input  
5 to a control electrode;

a smoothing circuit configured to smooth the output voltage from the switching transistor and output the smoothed voltage to the output terminal;

a selection circuit configured to control  
10 connection of a substrate gate of the switching transistor according to the input control signal, the selection circuit connecting the substrate gate to a drain of the switching transistor when the voltage on the input terminal is less than or equal to the voltage on  
15 the output terminal, and connecting the substrate gate to a source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal; and

a switching transistor control circuit  
20 configured to control a switching operation of the switching transistor so that the voltage output from the output terminal becomes the predetermined voltage.

23. The secondary cell charging circuit as  
25 claimed in claim 22, wherein the switching regulator

further comprises:

a selection control circuit that compares the voltage on the input terminal to the voltage on the output terminal, and controls the selection operation of  
5 the selection circuit according to a comparison result;

wherein

the selection control circuit controls the selection circuit to connect the substrate gate to the drain of the switching transistor when the voltage on the  
10 input terminal is less than or equal to the voltage on the output terminal, and controls the selection circuit to connect the substrate gate to the source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output  
15 terminal.

24. The secondary cell charging circuit as claimed in claim 22, wherein the selection operation of the selection circuit is controlled by an external  
20 selection control circuit according to the voltage on the input terminal and the voltage on the output terminal so that the selection circuit is controlled to connect the substrate gate to the drain of the switching transistor when the voltage on the input terminal is less than or  
25 equal to the voltage on the output terminal, and connect

the substrate gate to the source of the switching transistor when the voltage on the input terminal is greater than the voltage on the output terminal.

5           25. The secondary cell charging circuit as claimed in claim 23, wherein the switching regulator further comprises:

10           a switching circuit that connects a gate of the switching transistor with the drain of the switching transistor;

wherein

15           when the voltage on the input terminal is less than or equal to the voltage on the output terminal, based on a control signal from the selection control circuit, the switching circuit connects the gate of the switching transistor to the drain of the switching transistor while the switching transistor control circuit stops output of the control signal to the gate of the switching transistor; and

20           when the voltage on the input terminal is greater than the voltage on the output terminal, based on the control signal from the selection control circuit, the switching circuit disconnects the gate of the switching transistor from the drain of the switching transistor while the switching transistor control circuit

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outputs the control signal to the gate of the switching transistor.

26. The secondary cell charging circuit as  
5 claimed in claim 25, wherein the smoothing circuit includes a synchronization rectification transistor that is connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,

10           wherein

the switching transistor, the synchronization rectification transistor, the selection circuit, the selection control circuit, the switching transistor control circuit, and the switching circuit are integrated  
15 into one IC chip.

27. The secondary cell charging circuit as  
claimed in claim 25, wherein the smoothing circuit includes a synchronization rectification transistor that  
20 is connected to the switching transistor in series and is controlled by the switching transistor control circuit to be switched on or switched off,

wherein

the switching transistor, the synchronization rectification transistor, the selection circuit, the  
25

switching transistor control circuit, and the switching circuit are integrated into one IC chip.